ON SOME RECENT ADVANCES IN SPECTRUM ANALYSIS RELATING TO INORGANIC AND ORGANIC EVOLUTION.[1]

IN the last lecture I dealt with that new development of spectrum analysis which has enabled us to discuss, with greater fulness than was possible before, the various chemical conditionings in the different regions of our system as marked out for us by the Milky Way. I now have to refer to another development in a somewhat different direction. We have, as I think you will agree, by the discussion of the relation of the celestial bodies of all sorts to the Milky Way, demonstrated that the evolution of the cosmos in all probability took place from the gradual condensation of swarms of meteorites; and that such swarms are still more numerous there, and give rise to the new stars, bright-line stars and variable stars which are most numerous in its plane. When this work was begun our knowledge was so incomplete that a continuous chain of chemical facts was out of the question; but, thanks to the advances to which I have now to refer, we can deal with this cosmical evolution from a chemical standpoint, and what we have to do to-night is to consider the result of this inquiry.

I may begin by saying that now the gaps in our knowledge have been filled up, we find ourselves in the presence of a chemical evolution which is really majestic in its simplicity. Such a chemical evolution was suggested by me many years ago now, to explain the few stellar facts with which we were then familiar; but I do not propose to take up your time with any historical allusions; I must point out, however, that we to-night are in a very much better condition to consider this problem than we have ever been before, because at the present moment we have tens of thousands, I might almost say hundreds of thousands, of coordinated facts to go upon.

The first point I have to refer to is this: we have brought the sun and the stars together into line in all matters relating to the discussion of the effects of higher temperatures. The photographs taken during the recent solar eclipses show that when we deal with the hottest part of the sun that we can get at, which is hotter than that part of the sun which produces the well-known absorption spectrum marked by the so-called Fraunhofer lines, we are not in an unknown territory at all, but are brought face to face with similar phenomena to those in the atmospheres of stars which are hotter than our sun. The bright-line spectrum of the sun's chromosphere seen during an eclipse shows us the effects produced by heat in the hottest part of the sun that we can reach; these we can compare with the dark lines of a star which contains absorption lines very different from those represented by the Fraunhofer lines, and we find that they correspond almost line for line.

In this manner then we have an opportunity of correlating all the facts which have been obtained during the last, let us say, thirty years, in relation to the sun, with more recent facts than have been gathered with regard to the stars. In this work we were, by hypothesis, watching the effects of dissociation as the temperature rose higher and higher; but if we change our point of view, if we consider the phenomena no longer from the point of view of dissociation but from that of evolution, we find at once that the facts recently garnered carry us very far indeed along a new line of thought.

Let me give you an idea of what I mean. Let us deal, for instance, with well-known chemical compounds, say chloride of sodium, that is common salt, and oxide of iron, that is iron-rust. We have no difficulty in recognising the fact that chlorine and sodium in one case and oxygen and iron in the other must have existed before their compounds, common salt and iron rust, could be formed or associated. Water is split into hydrogen and oxygen at a high temperature, so that there is a temperature above which the two gases would remain in contact but uncombined; when the temperature falls water is produced. Dissociation, therefore, in all its stages must reveal to us the forms the coming together of which has produced the thing dissociated or broken up by heat. If this be so, the final products of dissociation or breaking up by heat must be the earliest chemical forms. Hence we must regard the chemical substances which visibly exist alone in the hottest stars as representing the earliest evolutionary forms. That, I think, is pretty obvious.

If we were only dealing with ordinary chemical forms it might be objected that it was only a question of *seeing*; that all chemical substances were really *present* in the reversing layer, that is the part of the atmosphere of the stars which we can study, but some only made their appearance; but I shall show later that the orderly progression includes lines of substances which we cannot see at all and others which we can only see at the highest possible temperatures in our laboratories.

Two or three times over I have used the words "evolution" and "evolutionary forms." What do these words really mean?

Perhaps I can give an idea of this by referring to another line of work altogether in which the word is frequently used and thoroughly understood. It is important that I should do this for another reason, which you will gather later. That line of work has to do, not with inanimate forms, like the chemical elements and the stars, but with living things, with so-called organisms. Some of my audience to-night doubtless remember Huxley's lectures here in 1860 On the Relations of Man to the Lower Animals, and most of you know that what we now recognise as one of the greatest triumphs of the century just ending was the determination of the truth of a so-called "organic evolution" in which we have, I suppose, the most profound revolution in modern thought which the world has seen.

That evolution tells us that each kind of plant and animal was not specially created, but that successive changes of form were brought about by natural causes, and that the march of these forms was from the more simple to the more complex. Organic evolution, in fact, may be defined as the production of new organic forms from others more or less unlike themselves; so that all the present plants and animals are the descendants, through a long series of modifications or transformations, or both, of a limited number of an ancient simpler type. We must not suppose that this change has gone on as if things were simply mounting a ladder; the truth seems to be that we have to deal with a sort of tree with a common root and two main trunks representing animal and vegetable life; each of these is divided into a few main branches, these into a multitude of branchlets, and these into smaller groups of twigs.

This new view represents to us the evolution of the sum of living beings; shows that all kinds of animals and plants have come into existence by the growth and modification of primordial germs. Now I want just to say that this is no new idea, it is the demonstration which is new to us in our present century and generation; we have really to go back to the seventeenth century, if indeed we must not go as far back as Aristotle, for the first germs of it; but with regard to the history, however, I have no time to deal with it. There are two or three points, however, to be considered in regard to this evolution. The individual organic forms need not continuously advance; all that is required is that there shall be a general advance—an advance like that of our modern civilisation—while some individual tribes or nations, as we know, stand still, or become even degenerate. With this reservation; the first forms were the simplest. It may be that as yet we know really very little of the dawn of geological history; that the fossiliferous rocks are nowhere near the real base. This conclusion has been derived by Prof. Poulton[1] from the complexity of the forms met with in them; still we find that we have not to deal with such a vast promiscuous association of plants and animals of lowest and highest organisation as we know to-day; we deal relatively only with the simplest. The story both with regard to plants and animals is alike in this respect.

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[1] A Lecture to Working Men, delivered at the Museum of Practical Geology on Monday, April 24, by Sir Norman Lockyer, K.C.B.

Let me deal with the plants first. The first were aquatic—that is to say, they lived in and on the waters. So far as we know, the first plant life was akin to that of the algæ which include our modern seaweed, moss-like plants followed them, and then ferns, and it is only very much later that the forms we know as seed plants with gaily coloured flowers living on the land made their appearance. The general trend of change amongst the plants has been in the direction of a land vegetation as opposed to one merely in or on the surface of the waters, and some present seaweeds exhibit the initial simplicity of plant-structure which characterised the beginning of vegetable life, while the seed plants I have mentioned are of comparatively late development; but we still have our seaweed; so that with all the change in some directions some forms like the earlier survive.

After this explanation, relating to work in an apparently different direction, you will have no difficulty in understanding the meaning I attach to the word "evolution" in relation to stars and the chemical elements which visibly exist in them, so far as the history of plant change is concerned; but we are not limited to plant life. The same conceptions apply to animal life, and it is important for my subject that I should refer to that also. What do we find there? We are brought face to face with the same progression from simple to complex forms. This is best studied by a reference to the geological record.

Stratigraphical geology is neither more nor less than the anatomy of the earth,[2] and the history of the succession of the formations is the history of a succession of such anatomies; or corresponds with development as distinct from generation. In stratigraphical geology, as can be gathered from any book on geology, we find the names of certain beds which contain certain different forms of animal and vegetable life. We begin with the Laurentian and Algonkian and then pass to the Cambrian, then to the Ordovician, the Silurian and Devonian, and so on through a long list of beds and geological strata until we come eventually to the Recent, that is to say, the condition of things which is going on nowadays on the surface of the earth. And if we prefer to map those many different beds into more generic groupings, we begin with the Primary or Palæozoic, we pass on to the Secondary or Mesozoic, and then we finally reach the Tertiary or Cainozoic. The deposition of these beds and of the animal life which has been going on continuously on the surface while those beds have been deposited gives us the various changes and developments which have taken place with regard to animal forms. It is worth while to go a little into details and to indicate the changes in these forms which have taken place, in the most general way. Beginning with the Lower Cambrian, we find that the animal forms were represented by Invertebrata such as Sponges, Corals, Echinoderms, Brachiopods, Mollusca, Crustacea and many early Trilobites; not to mention true Fucoids and other lowly plant-remains. When we come to the Silurian, we find a large accession of the above forms, especially of Corals, Crinoids, and Giant Crustaceans (such as *Pterygotus*) and armoured animals (Ostracodermi) without a lower jaw, or paired fins; the beginnings of Vertebrate life, not yet fully evolved, and one lowly organised group of armoured fishes named *Cyathaspis* (without bone cells in their shelly-shield). Here, too, we meet with the first Air-breathers; the wing of a Cockroach, and several entire and undoubted Scorpions! Thus in addition we get vertebrates as opposed to invertebrates, and the first traces of the fishes. In the advance to the Devonian the fishes (associated with giant Crustacea) predominate; it has been called the age of fishes. In the next series, the Carboniferous, we find the first certain traces of amphibians, of which the early existence is like that of a fish: a state of things illustrated by the frog, which the majority of us in our early days have, I am sure, studied as a tadpole in its early stages; and some of these amphibians still retain fish-like characters. It is not until we arrive at the Permian that the true reptiles are met with, but in the next great series, the Triassic, we meet with a remarkable evolutionary group of Reptiles, the Theriodontia, or beast-toothed animals, because (unique among reptiles) they possess a dentition like a dog or a lion, with incisors, canines and cheek-teeth; the precursors doubtless of the succeeding Mammalian type. We pass easily thus from the reptiles to mammals which are related to them; for instance, the ornithorhynchus and the echidna are both Australian mammals which bring forth their young within the egg as do the reptiles. Well, after that we begin to deal with birds. The early birds were strikingly reptilian in some of their characters; and the pterodactyle, which many of you may have seen remains of in different museums, was really a winged reptile and not a bird. From that we gather that mammals and birds are variants of reptiles. When we progress from the Jurassic to the Recent, we find man making his appearance as a direct descendant of all those early forms. There is not much new in this. This, as I have said, is what Huxley largely demonstrated in this theatre thirty-nine years ago in a previous course of these Lectures to Working Men.

When we come to study the life-history of the various forms brought before us by the geological strata, we find it to vary considerably, a fact indicated by the presence or absence of the different genera in the various strata. We find that the trilobites, for instance, only appear in the very early geological formations; there is no trace of them in the recent, but if we take the annelids we find that they are continuous from the earliest to the latest formations; we still have our worms. Again we find that certain other organic forms made their appearance very low down in the time scale, forms which were not represented at all in the earlier Cambrian and Silurian, and that some of these are continuous to the present day. Let us take the story of the fishes. A great many fishes made their appearance at the Devonian stage, there were few in the Silurian; some of these stopped there, whereas others have been continued from the Devonian times to our own. Take, for instance, the Australian mudfish *Ceratodus*; to judge from the teeth this fish might well have lived on unchanged from late Palæozoic times until the present day! We see there is a tremendous variation of possible life-range, so to speak, with regard to these different forms, and the plant record, although necessarily more imperfect than the animal on account of the nature of the organism, tells the same story in its fragmentary evidence. In that way, then, the geologist has been able to bring before us the continuity of life in various forms from the most ancient geological strata to the most recent. The record may be incomplete, but is complete enough for my purpose. But that is not the only evidence of evolution to which I can refer.

The teachings of embryology confirm the argument based upon the study of geology, and suggest that the life-history of the earth is reproduced in the life-history of individuals. The processes of organic growth or embryonic development present a remarkable uniformity throughout the whole of the zoological series; and although knowledge is still limited, some authorities hold that there is the closest possible connection between the development of the individual and the development of the whole series of animal life. There are others, however, who do not regard the argument derived from embryology as a very convincing one. However this may be, if we study the embryos of the tortoise, fowl, dog and man, we find that there is a wonderful similarity between them at a certain stage. At a further stage of development the similarity is still borne out. This does not mean that a vertebrate animal during its development first of all becomes a tortoise, and then the various animals which are represented by these embryos; it simply means that they are all related inasmuch as there is continuity.

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[1] Presidential Address, Section D, British Association Meeting at Liverpool, 1896.

[2] Huxley, *Q. J. G. S.*, xxv. p. xliii.

After these references to plants and animals it should be clear what organic evolution really is, and therefore what evolution is generally. I wish next to bring before you some considerations having relation to the stratigraphical record.

The question for us now is—Is there any equivalent to this in the inorganic world? or, to put it in another way, in those facts which have been revealed to us by the presence of the various chemical forms in the stellar strata represented by stars of varying temperatures? That is the question.

When I referred in my last course of Lectures here to cosmical evolution, I said that there we dealt with a continuity of effects accompanied by considerable changes of temperature; from the gradual coming together of meteoritic swarms until eventually we had a mass of matter cold and dark in space. The various stars which represent the different changes have been got out and have, in fact, been arranged along a so-called temperature curve. As we ascend one branch of this curve the stars get gradually hotter and hotter till ultimately at the top we find the hottest stars that we know of. Then on the descending branch are represented the cooling bodies, and finally they come down in temperature until we reach that of a dark world like the companion of Sirius, of our own moon, and the planet in which we dwell.

We can now deal with all these bodies in relation to their chemistry. We find that in the hottest stars we get a very small number of chemical elements; as we come down from the hottest star to the cooler ones the number of spectral lines increases, and with the number of lines of course the number of chemical elements. I will only refer to the known substances, it looks as if at present we have still many unknowns to battle with. In the hottest stars of all, we deal with a form of hydrogen which we do not know anything about here (but which we suppose to be due to the presence of a very high temperature), hydrogen as we know it, the cleveite gases, and magnesium and calcium in forms which are difficult to get here; we think we get them by using the highest temperatures available in our laboratories. In the stars of the next lower temperature we find the existence of these things continued in addition to the introduction of oxygen, nitrogen and carbon. In the next cooler stars we get silicium added; in the next we get the forms of iron, titanium, copper and manganese which we can produce at the very highest temperatures in our laboratories; and it is only when we come to stars much cooler that we find the ordinary indications of iron, calcium and manganese and other metals. All these, therefore, seem to be forms produced by the running down of temperature. As certain new forms are introduced at each stage, so certain old forms disappear. In order to connect this work with the stratigraphical work, to which I have referred, I have recently tried to define these various star-stages by means of their chemical forms which they reveal to us; so that we may treat these stellar strata, so to speak, as the equivalent of the geological strata to which I have already called your attention.

From the hottest to the coldest stars I have found ten groups so distinct from each other chemically that they require to be dealt with separately as completely as do the Cambrian and the Silurian formations. Imitating the geologist, I have given the following names to these groups or genera beginning with the hottest, that is the oldest dealing with the running down of temperature:—Argonian, Alnitamian, Achernian, Algolian, Markabian [a "break in strata"], Sirian, Procyonian, Arcturian (solar), Piscian.

I have gone further, and defined the chemical nature of these stellar genera as the biologist defines the nature of any of his organic genera; we can say, for instance, that the Achernian stars contain chiefly hydrogen, nitrogen, oxygen and carbon, and to a certain less extent they contain proto-magnesium, proto-calcium, silicium and sodium,[1] and possibly chlorine and lithium; so that at last, by means of this recent development of spectrum analysis, we have been able really to do for the various stars what the biologist a good many years ago did for the geological strata.

Now, considering this inorganic evolution from the chemical point of view, there are several matters which merit consideration. We shall not get much help by thinking along several obvious lines, for the reason that in the stars we are dealing with transcendental temperatures; for instance, we must not make too much of the difference between gases and solids, because, at high temperatures all the chemical elements known to us as solids are just as gaseous as the gases themselves; that is to say, they exist as gases; at a high temperature, everything, of course, will put on the nature of gas. Those substances with the lowest melting points, such as lithium and sodium, will, of course, under our present conditions put on the gaseous condition very much more readily than other substances like iron and platinum, but those are considerations which need not be taken into account in relation to very high stellar temperatures; of course, there would be no solids at a temperature of 10,000° C.

Then with regard to metals and non-metals. Here again we really are not greatly helped by this distinction. The general conception of a metal is that it is a solid, and that therefore a thing that is not a solid is not a metal; but the chemical evidence for the metallic nature of hydrogen has been enlarged upon by several very distinguished chemists. With regard to non-metals, there are certainly very many. Carbon is supposed to be a non-metal, and it is remarkable that, so far as the stellar evidence which I have brought before you has gone, carbon seems to be the only certain representative of that group. I want to point out specially that the table of the chemical definitions of the various stellar genera which I show you, which contains nothing but hard facts, is perhaps, like the geological record, more important on account of what it indicates as to the presence of the chemical elements in the stars than it is for what it omits.

There are a great many reasons why some of the substances which may exist in these stars should not make their appearance. I wish to enlarge upon the fact that, seeing the very small range of our photographs of stellar spectra, and seeing that it does not at all follow that the particular crucial lines of the various chemical substances will reveal themselves in that particular part of the spectrum which we can photograph, that the negative evidence is of very much less importance than the positive evidence. I think it is very likely, for instance, that we must add lithium to the substances which we find in the table, we must certainly add sodium, and also aluminium, and chlorine possibly, but about sulphur at present I have no certain knowledge; you will see the reason for these references later on. At all events, we can with the greatest confidence point out the remarkable absence of substances of high atomic weights, and the extraordinary thing that the metals magnesium and calcium undoubtedly began their existence in the hottest stars long before, apparently, there is any obvious trace of many of the other metals which a chemist would certainly have been looking out for.

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[1] Campbell, "Astronomy and Astro-physics," 1894, xiii. p. 395.

In relation to this new work, the first point to make is that the chemical forms we see in the hottest stars are amongst the simplest. What is the justification for this statement? Well, there are two reasons. The chemist will acknowledge that if there be such a thing as chemical evolution, an element of low atomic weight is simpler, that is, less massive, than an element of high atomic weight. If we rely upon spectrum analysis we can say, when dealing with the question of "series," about which I hope to say something in my next lecture, that the elements which have the smallest number of "series" are in all probability simpler than those which have a large number, and this is still truer when we find that all the lines in the spectrum of a substance can be included in those rhythmical series, as happens in the case of the cleveite gases. So that the first stage of inorganic evolution, if there has been such an evolution, is certainly a stage of simplest forms as in organic evolution.

The next point is that the astronomical record, studied from the evolution point of view, is in other ways on all-fours with the geological record. We get the same changes of forms, I may say that we get the sudden breaks in forms, disappearances of old accompanied by appearances of new forms, and with this we get, whether we consider the atomic weight point of view or the series point of view, a growth of complexity.

The geological story is exactly reproduced. Now, here it is obvious that a very important point comes in. In inorganic evolution we are dealing with a great running down of temperature; how tremendous, no man can say. We know the temperature of our earth, but we do not know, and we can not define, the temperatures of the hottest stars. So that how great the temperature of the earth may once have been, supposing it to be represented by the present temperature of the hottest star, no man knows anything with certainty.

With regard to organic evolution, however, which has to do with the plant world and the animal world, there can have been no such running down of temperature at all. The temperature must have been practically constant. Please bear that in mind, because I shall have to refer to it later on.

It is proper that I should say that just as the work of Darwin in the nineteenth century was foreshadowed by seventeenth century suggestions, so the stellar demonstration which I have brought before you to-night has been preceded by hypotheses distinctly in the same direction. The first stage of chemistry, as you know, was alchemy. Alchemy concerned itself with transmutations, but it was found very early that the real function of the later science of chemistry was to study *simplifications*, and, of course, to do this to the utmost we want precisely those enormous differences in temperature which it appears the stars alone place at our disposal.

With regard to the general question of inorganic evolution, the first idea was thrown out in the year 1815 by Prout, who, in consequence of the low atomic weight of hydrogen, suggested that that gas was really the primary element, and that all the others, defined by their different atomic weights, were really aggregations of hydrogen, the complexity of the aggregation being determined by the atomic weight; that is to say, the element with an atomic weight of twenty contained twenty hydrogen units; with an atomic weight of forty it contained forty, and so on. The reply to that was that very minute work showed that the chemical elements, when they were properly purified and examined with the greatest care, did not give exactly whole numbers representing their atomic weights. They were so and so plus a decimal, which might be very near the zero point, or half-way between, and that was supposed to be a crushing answer to Prout's view. The next view, which included the same idea—that is to say, a physical connection between these different things as opposed to the view that they were manufactured articles, special creations, each without any relation whatever to the other, was suggested by Döbereiner in 1817, and the idea was expanded by Pettenkofer in 1850. Both pointed out that there were groups of three elements, such as lithium, sodium, and potassium, numerically connected; that is, their atomic weights being 7, 23, and 39, the central atomic weight was exactly the mean of the other two, $7 + 39 = 46$, divided by 2, we get 23. Another way, however, of showing that is that $7 + 16 = 23$, and $23 + 16 = 39$; the latter method suggests a possible addition of something with an atomic weight of 16.

In 1862 de Chancourtois came to the conclusion that the relations between the properties of the various chemical elements were really simple geometrical relations. That, you see, is a much broader view. It is not till 1864 that we come to the so-called "periodic law," which was first suggested by Newlands, and elaborated by Mendeléeff in 1869. According to this law, the chemical and physical properties of the elements are periodic functions of their atomic weights. Lothar Meyer afterwards went into this matter, and obtained some very interesting results from the point of view of atomic volumes. He showed that if we plot the atomic volumes of the different elements, arranged according to their atomic weights from left to right, there is a certain periodicity in the apices of the curve indicating the highest atomic volumes.

So far there was no reference to the action of temperature in relation to this, but in 1873 I suggested that we must have a fall of temperature in stars, and that the greater complexity in the spectra of certain stars was probably due to this fall of temperature. This idea was ultimately utilised by Sir William Crookes in an interesting variation of the periodic law, in which he assumes that temperature plays a part in bringing about the changes in the characters of the elements. Brodie, in 1880, came to the conclusion that the elements were certainly not elementary, because in what he called a "chemical calculus" he had to assume that certain substances, supposed to be elements, were really not so; and he then threw out the very pregnant idea that possibly in some of the hotter stars some of these elements which he predicted might be found. Nine years afterwards, Rydberg, one of the most industrious investigators of the question of "series" to which I have referred, stated that most of the phenomena of series could be explained by supposing that hydrogen was really the initial element, and that the other substances were really compounds of hydrogen; so that you observe he came back to Prout's first view in 1815.

All these ideas imply a continuous action, and suggest that there was some original stuff which was continuously formed into something more complex as time went on. That is to say, that the existence of our chemical elements as we know them does not depend upon their having been separately manufactured, but that they are the result of the working of a general law, as in the case of plants and animals.

You see at once that the stellar facts which have already been brought before you are entirely in harmony with the highest chemical thought, and indeed establish the correctness of its major contention. We may be said to pass from chemical speculation to a solid chain of facts, which doubtless will be strengthened and lengthened as time goes on. In all these changes we seem to be in the presence of a series of what chemists call polymerisations, that is, roughly, a series of doublings. The greater complexities may also have been brought about by the union of different substances. In either case, as temperature is reduced, we get a possibility of combinations which was not present before; so that more and more complex forms are produced.

That brings us to a possibility of considering the processes of inorganic evolution in relation to those of organic evolution. I have already referred to the fundamental difference in the conditions. We had a running down of temperature which no one could define in the case of the stars; in the case of the organic evolution going on under our present conditions, we cannot be very much removed from the temperature conditions of the Cambrian formations. That is a point which I have made before, and it is important to insist upon it; clearly there cannot have been any very great change of temperature during the whole cycle of organic life. Previous to it we have found complexity brought about by doublings and combinations, the result being, as I have already mentioned, more complex forms. Of course, at the dawn of organic life on the surface of the earth there may have been residua of the earlier chemical forms; that is to say, not all the elements which we found in the hottest stars had combined to form the substances of which the earth was composed. However this may be, the work of organic evolution, unlike that of inorganic evolution, must have been done under widely different temperature conditions, but the result has been the same; it has since provided us with another succession of forms getting more complex as time has gone on, and there is still a residuum of early forms. We are led then to the conclusion that life in its various forms on this planet, now acknowledged to be the work of evolution, was an appendix, as it were, to the work of inorganic evolution carried on in a perfectly different way. Although the way was different, still nature is so parsimonious in her methods—she never does a thing in two ways that can be as well done in one—that I have no doubt that when these matters come to be considered, as they are bound to be considered with the progress of our knowledge, we shall find a great number of parallels; but I am not looking for these parallels now. What I wish to drive at is a chemical point of view which I think of some importance in relation to what has gone before; it is a point which I wish to make depending upon the existence of those elements which make their appearance in the hottest stars. In inorganic forms, in those represented to us in the hottest stars and the stars of gradually lower temperature, we have forms produced by a junction of like or unlike forms. Very good; but the more of these junctions the more the early forms must have disappeared, unless we may take it that they may have been made occasionally to reappear by the destruction of the later forms: that is a point to bear in mind. If the simpler forms must go on doubling to provide the more advanced forms, then if all the simpler forms are so used up there will be none left, and the only chance of getting the simpler forms again is to destroy something which had been previously made; and we can quite understand, of course, that there were many conditions of this distruction possible at the time when the crust of the earth was being formed. But however that may be, the gaseous elements with the non-gaseous elements first formed, would be the chief chemical substances on the surface and over it. Now the substances over the crust, of course, would be the gases, oxygen, hydrogen, nitrogen, and from the stars we can suggest carbon combined with them; that is to say, hydrocarbons, carbonic acid, and so on. On the surface, whether the surface be one of land or water, we should expect, in addition to the low melting point metals lithium and sodium, those two metals which we know existed in the hottest stars long before the others, magnesium and calcium. I have told you that lithium probably and sodium certainly exist in some of the relatively hot stars; the evidence also suggests sulphur, and this is rendered more probable because of the simplicity of its spectrum-series. Now these are very remarkable associations, and seem far away from ordinary chemical considerations, but they are the most important substances in sea water.

Constituents of Sea Water.

Chloride of sodium	77·75
,, magnesium	10·87
Sulphate of ,, ...	4·73
,, lime	3·60
,, potash	2·46
Bromide of magnesium	0·21
Carbonate of lime	0·34

The most easily thinkable evolution under these circumstances would be that of organisms built up of these chemical forms, chiefly because they would represent the more mobile or the more plastic materials. You would not expect evolution to have begun in iron, you would have expected it to have begun in something which was the most mobile and the most plastic. The available matter then for this evolution would be those gases plus those metals and those non-metals to which I have referred. Now, mark this. Suppose you have this evolution; if the forms so composed were to be multiplied indefinitely, the available material would be used up and organic evolution would be brought just as certainly to a dead-lock as the inorganic evolution was brought to a dead-lock when there was no possibility of any considerable reduction of temperature. We should expect a tendency to growth among the organic molecules, I dare not call it an inherited tendency, but I feel almost inclined to do so, having the growth of crystals in mind. Now, suppose that after you have got these new organic forms, the results instead of being stable were emphatically unstable, and still better, suppose you could induce a dissolution or the destruction of parts or wholes, progress would always continue to be possible, and indeed it might be accelerated.[1]

The new organic molecules would ultimately not have the first user of the chemical forms left available by the inorganic evolution, but they would have the user of the gases and other substances produced by the dissolution of their predecessors. They would be shoddy chemical forms, it is true, but shoddy forms would be better than none. Under these circumstances and in this way, the organic kingdom would be allowed to go on; in other words, the dissolution of parts or wholes of the new organisms would not merely be an advantage to the race, but might even be an essential condition for its continuance.

It therefore looks very much as if we can really go back as far as these very early stages of life on our planet to apply those lines of Tennyson :—

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[1] My friend and colleague, Prof. Howes, has called my attention in this connection to Prof. Weismann's views ("Weismann on Heredity," vol. i. p. 112), who seems to have arrived at somewhat similar conclusions, though by a vastly different road. He says, in his "Essay on Life and Death," "In my opinion life became limited in its duration not because it was contrary to its very nature to be unlimited, but because an unlimited persistence of the individual would be a luxury without a purpose."

The general view I have put forward, however, suggests that perhaps it was not so much a question of *luxury* for the living as one of *necessity* in order that others might live; it was a case of *mors janua vitae.*

The whole question turns upon the presence or absence, in all regions, of an excess of the early chemical forms ready to be used up *in all necessary proportions.* Hence it may turn out that the difficulty was much greater for land- than for sea-forms, that is, that dissolution of parts or wholes of land-forms proceeded with the greater rapidity. It is a question of the possibility of continuous assimilation (see Dantec, "La Sexualité," p. 11), and the word "parts" which I have used refers to the somatic cells, and not to the "immortal" part of living organisms.

> " So careful of the type she seems,
> So careless of the single life."

We have arrived, then, at a condition in which the same material may be worked up over and over again; in this way ultimately higher forms might be produced. Now, if to this dissolution, as a means of giving us new material, we add reproduction, then we can go a stage very much further. If we take bi-partition, which was the first method of multiplication, as we know both in the vegetable and animal world, we have a multiplication of forms by halving instead of the inorganic multiplication of forms by doubling, then we can have a very much increased rate of advance.

These then, roughly, are the conclusions as to an organic evolution which are suggested by the stellar evidence as to inorganic evolution, and the collocation of the simplest forms noted in the hottest stars.

Let us turn finally to the facts. Biologists, as I have said before, are very much more happy than astronomers and chemists, because they can see their units. A chemist professes to believe in nothing which he does not get in a bottle, although I have never yet seen the chemist who was ever happy enough to bottle an atom or a molecule as such ; but the superstition still remains with them, and they profess to believe in nothing that they cannot see. Now, the organic cell is the unit of the biologist, which is itself a congeries of subordinate entities, as a molecule is made up of its elementary atoms, manifesting the properties common to living matter in all its forms.

The characteristic general feature of the vegetable activity of the plant forms is their feeding upon gases and liquids, including sea-water. The progress of research greatly strengthens the view that there was a common life plasm, out of which both the vegetable and the animal kingdoms have developed. Be that as it may, you see the vegetable grows upon these chemical forms to which I have referred, and the animal feeds either upon the plant or upon other animals which have in their turn fed upon plants ; so that there we get the real chemical structure of the protoplasm, of the real life unit, in our organic evolution.

The last question, then, that I have to touch upon is this. Is there any chemical relation between the chemical composition of the organic cell and the reversing layers of the hottest stars—the reversing layer being that part of a star's anatomy by which we define the different genera ?

When we come to consider the chemical composition of this cell we find it consists of one or more forms of a complex compound of carbon, hydrogen, oxygen, nitrogen, with water, called protein ; and protoplasm, of which you have all heard, the common basis of vegetable and animal life, is thus composed. This substance is liable to waste and disintegration by oxidation, and there may be a concomitant reintegration of it by the assimilation of new matter.

The marvellous molecular complexity of the so-called simple cell may be gathered from the following formulæ for hæmoglobin :

Man ...	C 600	H 960	N 154	Fe 1	S 3	O 179
Horse ...	C 712	H 1130	N 214	Fe 1	S 2	O 245.[1]

Various different percentage compositions have been given of this protoplasm, but I really need not refer you to them. It is more important to consider the other chemical substances which go to form it, for there are others beside which it is of interest to study from our stellar point of view. I quote from Mr. Sheridan Lea.[2]

" Proteids ordinarily leave on ignition a variable quantity of ash. In the case of egg-albumin the principal constituents of the ash are CHLORIDES of SODIUM and potassium, the latter exceeding the former in amount. The remainder consists of SODIUM and potassium, in combination with phosphoric, sulphuric and CARBONIC acids, and very small quantities of CALCIUM, MAGNESIUM and iron, in union with the same acids. There may be also a trace of SILICA."

My point is that the more one inquires into the chemistry of these things the more we come back to our stellar point of view and to the fact that, taking the simplicity of chemical form as determined by the appearance of these different chemical substances in the hottest stars as opposed to the cooler ones, and in relation to the " series " of spectra which they produce, we come to the conclusion that the first organic life was an interaction somehow or other between the undoubted earliest chemical forms. Not only have we hydrogen, oxygen and nitrogen among the gases common to the organic cell and the hottest stars, but those substances in addition which I have indicated by capitals.

Surely we have here, I think, thanks to some of the recent advances made by spectrum analysis, a quite new bond between man and the stars.

We shall consider in the next lecture the simplicity of chemical forms as evidenced, not by atomic weight, but by the study of spectrum-series, to which I have already made two or three references.

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[1] " Verworn," p. 104.

[2] " The Chemical Bases of the Animal Body," p. 5.

THE BERLIN TUBERCULOSIS CONGRESS (1899).

THE Congress, which has just brought its proceedings to a close, was not, as has been frequently stated in the medical and lay press, an International Congress ; it was a German Congress to which foreign delegates and communications were invited. The mass of communications were made in German, this being the official language of the Congress ; a few, some half-dozen, in English and French. The necessity, or at any rate advisability, of discoursing in German, may account for the very meagre manner in which English medicine was represented either privately or officially. It seemed somewhat anomalous that the staff of only one London consumption hospital (the North London) was represented at the Congress. Further, the English doctors practising at foreign health resorts, who probably have unrivalled opportunities for observing the different phases of consumption, and the influence of treatment upon them amongst better class patients, were for the most part conspicuous by their absence. This nonchalance is to be regretted, especially as the hygienic treatment of phthisis, a relatively, at any rate in its systematic form, new development, occupied some 50 per cent. of the whole time of the Congress.

The enormous amount of material at the disposal of the Committee was classified in two ways. All papers were in the first instance denominated as lectures (" Referate "), or discussion communications. For the former twenty minutes was allowed, for the latter ten. The subject-matter was divided into five Sections. I. Extent and Spread of Tuberculosis. II. Aetiology. III. Prophylaxis. IV. Treatment. V. Sanatorium Treatment.

Section I.—Dr. Bollingen (Munich) read a paper upon tuberculosis amongst domestic animals, and its relationship to tubercular disease in man. Amongst many important points, the lecturer emphasised the importance of milk as a source of tubercular infection to men, directly and indirectly. Indirectly in the sense that tuberculosis is very common amongst pigs, who get infected in considerable numbers from being fed with the milk of tuberculous cows. Dr. Krieger (Strassburg) discussed the re-